Chapter 6: Converter Circuits

6.1. Circuit manipulations

6.2. A short list of converters

6.3. Transformer isolation

6.4. Converter evaluation and design

6.5. Summary of key points

- Where do the boost, buck-boost, and other converters originate?
- How can we obtain a converter having given desired properties?
- What converters are possible?
- How can we obtain transformer isolation in a converter?
- For a given application, which converter is best?

6.2 - A Short List of Converters

An infinite number of converters are possible, which contain switches embedded in a network of inductors and capacitors.

Two simple classes of converters are listed here:

- Single-input single-output converters containing a single inductor. The switching period is divided into two subintervals. This class contains eight converters.
- Single-input single-output converters containing two inductors. The switching period is divided into two subintervals. Several of the more interesting members of this class are listed.
Single Input/Output/Inductor Converters

- Use switches to connect inductor between source and load, in one manner during first subinterval and in another during second subinterval
- There are a limited number of ways to do this, so all possible combinations can be found
- After elimination of degenerate and redundant cases, eight converters are found:
  - *dc-dc converters*
    - buck
    - boost
    - buck-boost
    - noninverting buck-boost
  - *dc-ac converters*
    - bridge
    - Watkins-Johnson
  - *ac-dc converters*
    - current-fed bridge
    - inverse of Watkins-Johnson

Unipolar Output Converters

1. **Buck**
   \[ M(D) = D \]

![Buck Circuit Diagram]

2. **Boost**
   \[ M(D) = \frac{1}{1 - D} \]

![Boost Circuit Diagram]
Unipolar Output Converters (cont.)

3. Buck-boost

\[ M(D) = -\frac{D}{1-D} \]

4. Noninverting buck-boost

\[ M(D) = \frac{D}{1-D} \]

Bipolar Output Converters

5. Bridge

\[ M(D) = 2D - 1 \]

6. Watkins-Johnson

\[ M(D) = \frac{2D-1}{D} \]
Bipolar Output Converters (cont.)

7. Current-fed bridge

\[ M(D) = \frac{1}{2D-1} \]

8. Inverse of Watkins-Johnson

\[ M(D) = \frac{D}{2D-1} \]

Example Two-Inductor Converters

1. Čuk

\[ M(D) = -\frac{D}{1-D} \]

2. SEPIC

\[ M(D) = \frac{D}{1-D} \]
3. Inverse of SEPIC

\[ M(D) = \frac{D}{1-D} \]

4. Buck

\[ M(D) = D^2 \]

6.3 - Transformer Isolation

Objectives:

- Isolation of input and output ground connections, to meet safety requirements
- Reduction of transformer size by incorporating high frequency isolation transformer inside converter
- Minimization of current and voltage stresses when a large step-up or step-down conversion ratio is needed—use transformer turns ratio
- Obtain multiple output voltages via multiple transformer secondary windings and multiple converter secondary circuits
Ideal Transformer Model

\[
\frac{v_1(t)}{n_1} = \frac{v_2(t)}{n_2} = \frac{v_3(t)}{n_3} = \ldots
\]

\[0 = n_1i_1(t) + n_2i_2(t) + n_3i_3(t) + \ldots\]

Transformer Saturation

\[
B(t) \propto \int v_1(t) \, dt
\]

saturation

\[
slope \propto L_M
\]

\[
H(t) \propto i_p(t)
\]
Transformer Reset

• “Transformer reset” is the mechanism by which magnetizing inductance volt-second balance is obtained

• The need to reset the transformer volt-seconds to zero by the end of each switching period adds considerable complexity to converters

• To understand operation of transformer-isolated converters:
  • replace transformer by equivalent circuit model containing magnetizing inductance
  • analyze converter as usual, treating magnetizing inductance as any other inductor
  • apply volt-second balance to all converter inductors, including magnetizing inductance

Buck-derived Isolated Converters

![Buck-derived Isolated Converter Diagram]

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Full Bridge Converter